CHAPTER 7

SCIENCE IN FIRST URBANIZATION

1. PRELIMINARY REMARKS : MATHEMATICS

The difficulties in discussing the mathematical achievements during the period of Frst Urbanization, though well-known, may be briefly recapitulated. We have no literary evidence, testifying to this—nothing comparable to what is available in the other two primary centres of "the urban revolution", like the clay tablets of Mesopotamina or the papyrii of Egypt.

It is difficult, of course, to reject outright Childe's conjecture of possible mathematical documents of the Harappan Culture being lost with the unknown perishable materials on which these could have been recorded, specially because of his two arguments. First, the Harappan script, which survives for us mainly on the "seals", could not possibly have been invented just for the purpose of inscribing on these ; there are therefore grounds to presume that the script was invented to meet some other requirements of the urban centres. Secondly, on the analogy of Mesopotamia and Crete, it is not *prima facie* absurd to think that the main impetus leading to the invention of the script in the urban centres of the Harappan Culture could be accounts keeping. This must have been required not only for the city administrators, say in charge of the huge granaries from which were catered the basic needs of the whole-time urban specialists and others who were themselves not direct producers, but also for the traders of merchants of the Harappan cities, about whose existence there can be no doubt. At the same time, there is a limit beyond which a hypothesis can be built up merely on the evidence of the unknown. In any case, even admitting the possibility of mathematical documents of Harappan Culture perishing with the unknown materials on which these might have been documented, it is impossible for us today to form any definite and systematic idea of the nature of the mathematical activities in the period of First Urbanization.

But all this does not at all mean that we are totally debarred from forming any idea whatsoever about the possible mathematical activities in the Harappan Culture. Though without any direct literary evidence, there are a number of indi-

sputable archaeological data which want us very strongly to *presume* that there had been considerable mathematical activity in the Harappan Culture ; we have even very reasonable grounds to infer the nature of the mathematical activities, though at the present stage of research, only in scrappy outlines and perhaps somewhat tentatively. Fortunately, some highly competent scholars have already applied their minds to the subject. They include V. B. Mainkar, M. N. Deshpande

2. THE ARCHAEOLOGICAL DATA

and others, on whom we shall freely draw.

What, then, are these archaeological data ?

To begin with, a number of actual mathematical instruments are found among the ruins of the Harappan sites. Deshpande gives the following list of these :

1. A neatly finished piece of shell from Mohenjo-daro showing in its extant form nine divisions ; it is unanimously accepted by the archaeologists as the remain of a measuring scale.
2. A bronze rod from Harappa, also viewed as the remain of another measuring scale.
3. A small measuring rod of ivory from Lothal.
4. 'A peculiar object also from Lothal was probably used as a compus for measuring angles.'
5. "Terracotta plumb-bobs of different sizes from Lothal with or without vertical rods are also reported from Mohenjo-daro and Harappa."
6. "A graduated scale intended perhaps for measuring has also been reported from Kalibangan."

Before passing on to discuss these in some detail, it is necessary to add that these are not the only archaeological data for inferring mathematical activities in the Indus Valley Civilization. To the above list are to be added the following :—

1. Units of weights uniformly in circulation throughout the vast area covered by the Harappan Culture. We are indebted to Mainkar for a brilliant systematisation of these along with the mathematical deductions from their evidences.
2. Standardization of the brick-measures and the geometrical principles followed in their making, to which may be added

1. M. N. Deshpande, IJHS, VI, 1. 10-11.

the geometrical principles usually followed by the "seal"-cutters.

3. The monumental remains of fortifications, granaries, public-baths, roads, house-blocks excavated at Harappa, Mohenjo-daro and recently also at Kalibangan and the remains of a dockyard at Lothal. Geometrical knowledge apart, we are obliged to deduce from these the knowledge of mathematics in other forms, like calculations of the number of workers, engineers, architects required for their construction and hence the amount of food etc. necessary for their subsistence.

4. Certain designs on Harappan potteries, like "squares inscribed in compus-drawn intersecting circles" appear to be pointers to the theory and practice of geometry.

Thus, notwithstanding the fact that no written document testifying to the mathematical activities of the Harappans is available for us, we have many evidences that remain inexplicable without the admission of mathemat'cal activities on their part. It remains for us to see if any light is possibly thrown by what we propose to call "the method of retrospective probing", *i.e.* deductions from the mathematical documents of later times which are evidently in need of the assumption of antecedent historical development.

3. THE SCALES OF LENGTH MEASURE

We begin with a brief account of the scales or instruments for measuring length, fragmentary remains of which are so far recovered from the ruined sites of the Harappan Culture.

These, as we have already said, are three. Of these, one was first reported by Mackay in 1938 in his *Further Excavations at Mohenjo-daro*[2], the second first reported by Vats in 1953 in his *Excavations at Harappa*[3] and the third first reported in 1973 by Rao.[4]

2. Mackay FEM, Pl. cvi. 30; also pp. 404-5.
3. Vats EH Pl. CXXV, 39a and p. 365.
4. S. R. Rao, in IAR, 59-60, pl. xiii. b., also p. 17. cf. also S. R. Rao, LIC 105: the one "found at Lothal is said to be more accurate, as the divisions marked on it (Fig. 28, pl xxxii A) are smaller than those marked on the scale from Mohenjo-daro. A graduated scale is reported from Kalibangan too, but details are not known".

According to the sites in which these are found, therefore, these three scales may be referred to as the Mohenjo-daro-scale, the Harappa-scale and the Lothal-scale. The physical descriptions of these scales, though oft-repeated in recent archaeological literature, may briefly be recapitulated.

The Mohenjo-daro-scale is made of shell, the Harappa-scale of bronze and the Lothal one of ivory. The selection of the materials has its own interest, not merely because of their durability but also of their comparative resistance to easy contraction or expansion due to temperature variation. Much more important for our own discussion, however, is the mathematical aspects of the scales—the unis of linear measures suggested by these.

The Mohenjo-daro scale first[5] :

> It has nine graduations and there is a hollow circle on one graduation, while on the fifth graduation therefrom, there is a large circular dot. This sequence would indicate that a hollow circle would occur five graduations after the dot and so on. The graduation lines are made with a fine instrument and are uniformly thick and properly graded in length. The distance between two adjacent lines is, on an average, 6.7056 mm. The accuracy of the graduations is very high, as the mean error of graduation is 0.075 mm. Thus the length contained between five graduations is 33.528 mm and the length between one hollow circle and the next would be 67.056 mm. This length of 67.056 mm apparently constitutes the major graduation of the scale. Since the sub-division of the major graduation of the scale is decimal, we may reasonably assume that the original scale had ten major graduations on it. This assumption leads us to the conclusion that the length of the total scale could be 670.56 mm. This is a very interesting result, as the total length of the scale is practically equal to two-thirds of a metre. It is also noteworthey that the length-scale appears to be decimally divided like the metre.

We shall presently see that the evidence of the series of weights also found in the Harappan Culture corroborates the decimal system having been current there. But let us first note the system of length measures as evidenced by the scales. Mackay, to whom we owe the first report on the Mohenjo-daro scale, also drew our attention to the decimal system on which it was fashioned, and observed :[6]

5. Mainkar in FIC 146.
6. Mackay FEM, 404-5.

The decimal system of liner-measure is known in Egypt as early as the Fourth Dynasty, and a decimal division of the cubit in the Twelfth Dynasty has been noted by Kahun. Both the decimal and the sexagesimal systems were in use in early Sumer, though it is not yet known which came first. According to Langdon, both systems were in use in Jemet Nasr; and on the Fara tablets, also, which must be dated to the Early Dynastic period, the two systems were used. We are told, however, that a purely decimal system is found on the Proto-Elamite tablets; and it may be that it was from Elam that the system was introduced into N.W. India, though on the basis that every man has ten fingers it seems to me that the decimal system should be more primitive than the sexagesimal, and that it may have had independent origins.

In view of the trade relations between the Harappans and Mesopotamians. diffusion of scientific ideas need not be necessarily ruled out, though in the absence of any positive evidence in favour of it, it seems safer not to indulge in conjectures. In any case, the systematic and uniform use of the decimal system in the Harappan Culture—about which we shall presently see more—is a prominent feature of the period of First Urbanization and it could have interesting consequences in the comparatively later period of Indian culture. For the present, however, let us pass on to the other scales found among the Indus ruins.

S. R. Rao, as we have already noted, has reported a truncated piece of ivory scale at Lothal:[7]

The Lothal scale is 15 mm broad, 6 mm thick and has a length of 128 mm. Only 27 graduation lines can be easily seen, the length over which these lines are spread being 46 mm. The average distance between the graduation lines is, therefore, 1.704 mm. The sixth and the twentyfirst graduation lines are longer than the rest. The length between these two graduation lines is, by calculation, 25.56 mm.

Is it, then, indicative of some different unit of length measure than was current in Mohenjo-daro? Mainkar[8] has answered this question and we may quote him at some length:

The Mohenjo-daro scale and the Lothal scale are apparently different but on analysis they prove to be practically equal. It will be noticed that 20 divisions of Lothal scale are equal to 34 mm, which is almost equal to the distance between the hollow circle and

7. Mainkar in FIC 146.
8. *Ibid.*

the circular dot on the Mohenjo-daro scale, namely 33.53 mm. This fact establishes that the two scales are related, but their division into smaller graduations are different. The smaller graduations of the Mohenjo-daro scale are at every 6.706 mm, while those of the Lothal scale are at 1.7 mm, the ratio being 4 Lothal graduations are equal to one graduation of the Mohenjo-daro scale. The smallness of the Lothal scale-graduation indicates that it was used for finer measurements.

One example of the need for such finer measurement is suggested by S. R. Rao: "The Indus seals can be measured more accurately in terms of the smaller divisions of the Lothal scale than in terms of the divisions of the Mohenjo-daro scale."[9] "This", observes Mainkar, "is a very plausible and satisfying explanation."[10]

Much more important for our immediate discussion are two other points sought to be established by Mainkar. These are: (1) His view of the possible use of the Indus Valley scales of linear measurement in brick-making and architectural techniques in the period of First Urbanization, and (2) His attempt to correlate the units of length measures with the same in later Indian history.

Before passing on to these—particularly the first of the two points—we may as well note the very legitimate caution with which he begins this discussion:[11]

> While comparing the theoretical and actual length of linear measures, it should be borne in mind that, even under modern conditions, it requires very costly machinery to draw lines to a thickness of 0.050 mm. Further, it is difficult to read, with the naked eye, graduation lines separated by a distance of less than half-a-milimetre. It is, therefore, necessary to understand that when the calculated length of say, 68 mm, is equated with an actual distance of, say 67 mm, we may not be introducing a substantial error in our argument. Such equations have always to be treated as guidelines rather than strict mathematical formulations.

With this caution in mind, let us see how Mainkar wants to show that "the three scales discovered in three widely separated centres of the Indus Civilization are interrelated, and can

9. S. R. Rao, in LIC 107.
10. Mainkar in FIC 146.
11. *Ibid.*

explain statisfactorily the dimensions of the bricks, the baths, the dock and the like."[12]

The bricks first. Mainkar considers the following five "nominal sizes" of the bricks found in the different centres of the Indus Civilization :

1. Mohenjo-daro : 225×115×57 mm.
2. Lothal and Mohenjo-daro : 250×125×60 mm.
3. Lothal : 280×140×65 mm.
4. Kalibangan and Mohenjo-daro : 300×150×75 mm.
5. Kalibangan : 400×200×100 mm.[13]

We have already noted that the standardization of the ratio of the three dimensions of the bricks—the length, breadth and thickness—as 4 : 2 : 1 is extremely significant from the viewpoint of efficient bonding, and it reminds us of the ratio of the sides of the standard bricks being used in our times. For the present let us note Mainkar's analysis of how the determination of the brick-sizes mentioned above appear to be indicative of the use of the Indus Valley scales. As he observes :[14]

> It is obvious that the longest side of the Mohenjo-daro brick, namely 225 mm. is nearly 9×25.6 mm. i.e. 9 times the major graduation of the Lothal scale. The longest side of the Lothal brick, namely 250 mm, is equal, within limits of error to 150 small graduations of the Lothal scale (1.7 mm. of each) or 10 major graduations of 25.56 mm. each, while the longest side of the larger brick, namely 280 mm is made by the addition of one major graduation or 15 small graduations on the Lothal scale, i.e. 11 large graduations (25.56×11 mm).
>
> The brick with 300 mm side is a further extension of the above principle and comes to 180 Lothal small graduations or 12 large Lothal graduations (25.56×12 mm). In like manner the 400 mm brick would appear to be equal to 16 larger divisions of the Lothal scale (25.56×16 mm).
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> This analysis shows that perhaps, bricks were made in dimensions which were integral multiples of large graduations of the Lothal scale, namely 25.56 mm. The other dimensions of the bricks, being in the ratio of 1 : $^1/_2$: $^1/_4$ also fall into a rational number of Lothal graduations.

12. *Ibid* 147.
13. *Ibid.*
14. *Ibid.*

Admitting this, we have to accept that brick-making according to the application of some definite scale which we come across practically throughout the *Sulva-sutra*-s is indicative of a very ancient tradition, inasmuch as this tradition goes back to the period of the First Urbanization. This, in other words, means that the relation of mathematical calculation with brick-technology has a hoary past.

In view of the large number of brick-types mentioned in the Sulva texts each with very specific measurement in terms of the units of linear measures accepted by the texts, it would be a laborious process to try to assess the measurements of the Sulva bricks in terms of the scales of the Harappan Culture. Besides, that is not necessary for our main argument, namely that it is not *prima facie* impossible to try to trace the tradition of the application of mathematical calculation to brick technology to the ancient Harappan Culture. This tradition, once accepted, may explain the meticulous care taken by the brick-makers of our Sulva texts to be specific or accurate about the measures of the brick-types, a large number of which they had to improvise in order to meet the requirements of the peculiar structures they were asked to execute. Incidentally, this technique of improvising new and newer brick-types, too, could have its roots in the Harappan culture, where, apart from the standardised bricks, we also meet with various other brick-types, like the T-shaped one assumed as needed for covering the drains and the wedge-shaped bricks used for the construction of wells, drains or the grinding floor of the granaries.

But there is another point of considerable interest which may as well be noted in this connection. In spite of various conjectures, the fact remains that we have no definite knowledge of the language of the peoples in the Indus Valley Civilization. It is, therefore, futile to speculate on the possible terminologies used by the Harappan peoples for the units of length measures. In the history of Indian culture, the earliest evidences for such terminologies are to be found in the *Sulva-sutra*-s and *Arthasastra*. In both, the basic unit for length measure is called an *angula*, literally 'the finger'. For the sake of precision, however, the *Arthasastra* defines it as "the maximum width of the middle (part) of the middle finger of a middling man."[15] Whether the unit *angula* of the *Arthasastra* is exactly the same as understood in the *Sulva-sutra*-s may be

open to some discussion, for the *Arthasastra*[16] proposes to measure it in terms of eight *yavamadhya*-s (the width of the middle of eight *yava*-s) whereas the *Baudhayana Sulva-sutra*[17] conceives it in terms of fourteen grains of the *anu* plant (understood by Thibaut as *panicum miliaceum*). But we may note here one point of some interest. According to both the texts[18] the longer unit called *aratni* (losely translated as 'cubit' by Kangle) is conceived in terms of 24 *angula*-s and it is also the same according to Yallaya's explanation of Aryabhata[19] though the latter uses the word *hasta* instead of *aratni* (literally the length from the elbow to the tip of the little finger). In any case, the fact is that the term *angula* stands for the basic unit of length measure in later literature, inclusive of the Sulva texts and there are at least some hints suggesting correlation between the *angula* of the *Baudhayana Sulva-sutra* and of the *Arthasastra* as well as of much later astronomical works.

Earlier writers like J. F. Fleet[20] were satisfied by roughly equating the *angula* to 3|4th of an inch, which makes it 19.499 mm. On the basis of a more meticulous calculation, however, Mainkar equates the length of the *Arthasastra angula* to 17.78 mm. This gives a very interesting clue to correlate the basic unit of later linear measure, viz. the *angula*, to the length measure of the Lothal scale. As Mainkar[21] puts it :

> The author has shown, (in his articles) tracing the development of length and area-measures in India, that the *angula* which is the basic unit of length measures, mentioned in the *Arthasastra*, is 17.78 mm. This value is so nearly equal to the value of ten small graduations of the Lothal scale (1.703×10 mm), that they may be considered as being practically equal. If this is accepted, and Rao agrees with it, the entire series of length-measures specified in the *Arthasastra* falls in a pattern with the Indus scales. The author has shown in his articles mentioned above, that the length-measures used in India throughout later periods were related in some manner or other, with the length-measures specified in the *Arthasastra*. It is,

15. *Arthasastra*, ii. 20.7.
16. *Ibid* ii. 20.5.
17. *Baudh Sul Su.* i. 4.
18. *Arthasastra*, ii. 20. 12 ; and *Baudh. Sul Su.* i. 16.
19. Shukla and Sarma, *Aryabhatiya*, intro xliii.
20. J. F. Fleet in JRAS. 1912. 233.

therefore, possible to assert that the Indus length-measures had a very profound influence on the length-measures used in India up to a few years back.

S. R. Rao wants to go a step further :[22]

> It appears that both 'foot' and 'cubit' were treated as units for linear measures. The 'foot' is said to be of 13.2 ins. (33.5 cms.) and the 'cubit' varying between 20.3 and 20.8 ins. (51.5 and 52.8 cms). The houses in Lothal can be measured in terms of complete units of 'foot', e.g. House No. 159 (phase IV A) measures 40×20 units, and warehouse 117×123 units, the unit in each case being 13.2 ins.

But before passing on to see more of the application of mathematics to the brick-structures of the Harappan Culture, we may ask ourselves a simple question. Could it be that the correlation of the *angula* of the later texts inclusive of the Sulva-s with the linear measure of the Indus scales be itself an indication that wants us to seek the roots of the Sulva mathematics in the mathematical activities in the First Urbanization?

4. BRICK-TECHNOLOGY AND MATHEMATICS IN FIRST URBANIZATION

While analysing the *Sulva-sutra*-s we were led to the view that the mathematics codified in these texts is inconceivable without the tradition of highly sophisticated brick-technology. The texts give us the impression that this mathematical knowledge was above all the outcome to meet the theoretical requirements of the brick-makers, brick-layers, architects and other technicians, who were required to execute the construction of certain specified forms of brick-structures. At the same time, we were confronted with an apparently anomalous situation. The texts cannot but be placed in a period which, archaeologically speaking, was unaware of any sophisticated brick-technology. Hence we were led to raise the question concerning the possible roots of this mathematics in the mathematical activities of the First Urbanization, one of the most conspicuous features of which had been highly sophisticated brick-technology. But the first point that requires to be established before answering the

21. Mainkar in FIC 147-48.
22. S. R. Rao, LIC 107.

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21. Mainkar in FIC 147-48.
22. S. R. Rao, LIC 107.

question is that we have definite evidences indicating mathematical activities in Harappan Culture. We have just seen that the linear measures of the broken scales found among the ruins of the First Urbanization appear to foreshadow the basic unit of the linear measure assumed by the Sulva texts. We now pass on to discuss how far we are obliged to presume the application of mathematical knowledge from the remains of the brick-structures of the First Urbanization.

In default of anything directly documenting mathematical activities during the period of the First Urbanization, it is impossible of course for us to hope to have any systematic knowledge of Indus mathematics.

Nevertheless, it is important to note that serious archaeologists and other scholars have felt obliged to argue that the brick-structures of the First Urbanization remain unexplained without the assumption of the application of a good deal of mathematical knowledge.

Here is how M. N. Deshpande[23] puts the general argument :

> The monumental remains of fortifications, granaries, public-baths, roads and house-blocks excavated at Harappa, Mohenjo-Daro and recently at Kalibangan and remains of dockyard at Lothal imply a good deal of arithmetic and knowledge of geometry. Keeping of accounts for the construction of public buildings such as of labour and material would entail complicated calculations. Unfortunately, direct evidence of such accounting is not available. As regards the knowledge of geometry besides the few measuring rods and other instruments which have come to light... we have largely to depend for such deductions on the data supplied by the buildings themselves. It is obvious from the meticulous care the Harappans took in planning the city with well laid-out streets that they knew fundamentals of surveying. This would include knowledge of levelling as without detailed measurements it would not have been possible to plan the sewage system. The use of standardized bricks having plain rectangular faces, parallel sides, sharp, straight, right-angled edges including wedge-shaped bricks in the construction of circular wells so as to produce the inner and outer circumference would presuppose knowledge of geometry of parallels and circles.

Mainkar with his illuminating analysis of the correlation of the standard brick-sizes of the Indus ruins with linear mea-

23. M. N. Deshpande, in IJHS VI. No. 1. 9.

sures of the Indus scales, gives us some specific examples of the mathematical calculations implied by a number of the brick-structures of the First Urbanization. We quote him at some length :[24]

Turning to other sources of measurement the 'Great Bath' at Mohenjo-daro had average measurements of 11.89 m. × 7.01 m. with a depth of 2.44 m. Adjoining the 'Great Bath' were smaller rooms of 2.9 m. × 1.8 m. each. It is apparent that each of the smaller rooms had approximately ¼ of the average measurements of the Great Bath' (2.9×4=11.6 and 1.8×4=7.2). In their turn, the measurements of the smaller bathrooms are related to the bricks having 300 mm as the longest dimension. Thus, the longer side of the bathrooms is 10 times and the smaller side 6 times the longest side of the 300 mm brick. The longer side of the 'Great Bath' is equal to a length of 40 bricks and the smaller side to a length of 24 bricks the depth being equal to the length of 8 bricks.

Rao has recorded that the average measurements of the dock at Lothal are 214 m × 36 m, the foundations being 1.78 m wide and the walls above the ground 1.04 m. These measurements are interesting because 1.04 m is equal to 40 large graduations of Lothal scale (25.56 mm), while 1.78 m is equal to 1000 times the small graduations of (1.7 mm) of the Lothal scale or $66^2/_3$ large graduations of 25.56 mm. The major dimensions of the dock are in the proportion of 6 : 1. The dimension of 36 metres is 20 times the width of the foundations, namely 1.78 m. The latter value is in turn related to the small graduation of the Lothal scale by 1,000 times.

The width of the doors in the houses at Mahenjo-daro was about 1.02 m.; this is 40 times 25.56 mm. the large division of the Lothal scale or 15 times the large division of Mohenjo-daro scale, namely 67.06 mm.

There are numerous other dimensions and measurements which could be analysed. But, it is considered that the examination carried out so far is adequate for indicating that the three scales discovered in three widely separated centres of the Indus Civilization are interrelated, and can explain satisfactorily the dimensions of the bricks, the baths, the dock and the like.

All this may be taken as pointers to a very interesting line of research requiring the co-operation of archaeologists, architects and mathematicians for determining the nature of mathematical knowledge necessarily presupposed by the structural remains as well as by the decorative designs of the Indus relics. R. P. Kulkarni of the Maharashtra Enginnering Research

24. Mainkar in FIC, 147.

Institute, seems to be taking some step in this direction in his article *Geometry as known to the People of Indus Civilization.*[25] From the designs and figures on some "seals" corroborated by certain structural remains at Mohenjo-daro and Harappa, he argues that "the people of Indus Civilization might be knowing the following postulates and geometrical constructions" regarding "properties of rectilinear figures".[26]

"Postulates : (a) The diagonals of a square (or rectangle) divide it into equal areas. (b) The diagonals of a square (or rectangle) are of equal length. (c) The bisectors of the sides of the square cross each other at right angles.

"Constructions : (a) To divide a line of a given length into two equal parts. (b) To divide a line of a given length into any number of parts of equal length. (c) To divide a line of a given length into different lengths as required. (d) To construct a square|a rectangle of sides of given lengths and with accurate right angles. (e) Construction of dividing a given quare|rectangle into small squares|rectangles of equal areas. (f) To divide a rhombus (and, therefore, may be a triangle) into rhombuses (triangles) of equal area. (g) To draw two lines parallel to each other." Admitting all this, we are obviously reminded of some of the basic propositions discussed in the Sulva geometry.

Similarly, Kulkarni proposes to read the knowledge or the potentials thereof of "properties of a circle" and the "knowledge of area and volume of rectilinear figures" as forming part of the geometry as known to the people of the Indus civilization. Much of what he claims may appear to us as he himself admits, to be more or less conjectural[27] and hence may fail to create conviction of the mathematicians today. Besides, for the archaeologists, too, his article is likely to appear as but based on rather inadequate data, inasmuch as he depends for these mainly—even exclusively—on Marshall's *Mohenjo-daro and the Indus Civilization* and Mackay's *Early Indus Civilization*, showing no awareness at all of the spectacular results of the later archaeological works done at sites like Lothal,

25. R. P. Kulkarni IJHS, 1978, Vol. XIII No. 2. 117-124.
26. *Ibid* 119 ff.
27. *Ibid* 122.

Kalibangan etc. Such limitations of his article are, however, not to be misunderstood or misinterpreted as limitations of the basic direction of approach. On the contrary, it may be taken as a pointer to very fruitful research though requiring the collective efforts of working engineers, architects, mathematicians and of course the archaeologists. In any case, the evidence of the *Sulva-sutra*-s of the formation of geometry to meet theoretical requirements of the brick-technology cannot but invite us to explore the possibility of studying more intensively the geometrical knowledge of the Indus period, one of the most prominent features of which was very imposing brick-technology, though in default of any literary evidences it may be imposible for us to know if the mathematical activities during the period of First Urbanization was ever systematically codified as was done in the Sulva texts.

Incidentally the codification of the *Sulva* texts in their present form cannot but raise a number of highly intriguing questions. Even if we are allowed to postulate the codification of geometrical knowledge in the Harappan period on some unknown perishable materials, the fact remains that we do not yet know with certainty the language of the Harappans. In his recent work on *A Comprehensive Sulvasutra Word Index*, Axel Michaels gives us the impression that a considerable number of the technical words in these are apparently non-Sanskrit. Admitting this, we have no ground to argue that these non-Sanskrit words have roots in the Harappan language. Besides, a very large number of *Sulva* words are positively Sanskrit, as positive is the fact that the language and style of the composition of these works are Sanskritic. Since it will evidently be too much to assume that the *Sulva* texts were later adaptations by the Vedic priests of some unknown—or purely hypothetical—Harappan texts, the problem of the codification of the Sulva texts in their present form remains an open question. Perhaps only this much may be asserted that since the basic geometrical knowledge in these texts is inconceivable without the tradition of very sophisticated brick technology (which was there in the Harappan culture but totally absent in the period usually assigned to the *Sulva* texts), their mathematical core presumably came down from the Harappan past. Towards the beginning of the period of Second Urbanization some people belonging to the circle of the priestly elites somehow took

an absorbing interest in this ancient mathematics and codified it in Sanskrit, though freely drawing on "loan words" specially in matters concerning technological and terminological. However, there are likely to be many objections intertwined with unanswered questions even against such a hypothesis. Hence it seems reasonable to leave the question of the codification of the *Sulva* texts as an open one, requiring a good deal of further investigation.

5. SYSTEM OF WEIGHTS

At the present stage of research, whatever we may reasonably presume about the geometrical knowledge and its systematisation in the Indus Civilization, there are also other grounds to infer mathematical minds working during the period of First Urbanization. We shall mention here one of these, namely the system of weights.

We are indebted to A. S. Hemmy, who, in his chapter on *System of Weights at Mohenjo-daro* in Marshall's *Mohenjo-daro and the Indus Civilization*, initiated the analysis of the subject. Later archaeological work specially at Lothal has revealed more data related to the subject, necessitating a revised understanding of the system of weights in the Indus Valley Civilization. We are indebted specially to Mainkar who, in his paper on *Metrology in the Indus Civilization*, has given us a systematic account of the system of weights in Harappan Culture based on up-to-date evidences. It may be enough for our own purpose to follow the discussions of Hemmy and Mainkar to have some idea of the mathematics underlying the system of weights in the period of First Urbanization.

Before proceeding to this mathematics, it may be useful to note two points. First, what cannot but amaze the archaeologists today is the uniformity of the system of weights that prevailed unchanged for over five hundred years throughout the vast area covered by the Harappan Culture—an area which, as we have already said, is roughly estimated at 500,000 square miles. "Such uniformity of weights over such vast spans of distance and time is a unique feature in the history of metrology."[28] Secondly, the objects used for weighing pur-

28. Mainkar in FIC 141.

poses are "rectangular blocks, mostly of a tawny or light grey banded chert, but also of other hard rocks such as gneiss. In one on two cases their form is cylindrical, but for the most part it is cubical. The blocks are well finished and polished. and are generally in a good state of preservation... The results obtained by weighing these blocks show conclusively that they are weights belonging to a definite system."[29] This, again, appears to be something remarkable, particularly when compared to the weights in the other two primary centres of the Urban Revolution. As Mainkar[30] observes :

> The available information (Berriman 1953) shows that there were many systems of weights and measures prevalent in Egypt, and there was no uniformity in them even remotely comparable with that noted in the Indus valley. The Sumerians also could not claim comparable uniformity in the field of weights and measures. Even the shapes of the weights used in the Egyptian and Sumerian civilizations were entirely different. Some Sumerian weights were made in the shape of animals. The shapes of the Indus weights were highly practical.

Analysing the weights found in Mohenjo-daro and Harappa, Hemmy prepared a Table of the Denomination of Weights, which suggests that the system followed was partly binary and partly decimal. In 1973, Rao discovered at Lothal another system of weights which when tabulated, appears to be binarily arranged. The classification of Indus weights into partly binary and partly decimal does not appear to be logical to Mainkar[31] who, therefore, argues as follows :

> The practical approach would appear to be to take all these weights together and divide them afresh into two or more logical groups. It is obvious, to any observer that the decimal system is primarily used in the progression of the Indus weights. The principle used for the progression of the denominations of the metric weights is to multiply and divide the decimal unit by two. For example, take the unit of 100 g. By multiplying it by two, we get 200 g. dividing it by two gives 50 g. If the same operation is repeated with other decimal units the series of denominations obtained is 1, 2, 5, 10, 20, 50, 100, 200, 500 and so on. Thus the weights form a series in the ratio of 1 : 2 : 5 and decimal multiples of each of the numbers in this

29. Hemmy in Marshall's MIC 589. Mackay FEM 601 ff. who adds the analysis of 220 weights found by subsequent excavations.
30. Mainkar in FIC 141.

ratio. Applying this principle to the totality of the weights recorded by Hemmy and discovered by Rao, two distinct and well-knit series of denominations are obtained, as shown in (the following) Tables.

First Series of Weights

Mean Weight (Approx.)	Ratio (Approx.)
1.2184	0.05
2.285	0.1
5.172	0.2
13.792	0.5
27.584	1
55.168	2
137.90	5
271.33	10
546.70	20
1417.5	50
2701.4	100
5556.0	200
10865.0	500(?)

Second Series of Weights

Mean Weight	Ratio (Approx.)
0.871	0.05
1.770	0.1
3.434	0.2
8.5753	0.5
18.1650	1
33.3052	2
174.50	10
6903	500(?)

These two tables leave out only two weights of 6.829 grammes (or 6.896 grammes of Rao) and 4.3370 grammes, which happen to be approximately a quarter of 27.405 grammes and 18.165 grammes respectively and may have been used for special purposes. These two tables are formulated by the application of the same logical principle as has been used 4000 years later in the progression of the denominations of weights of the metric system.

It may also be noted that the weights of ratio unity in the two tables are rationally related to each other. The unit weight of 27.584 grammes of the first series, is 50 per cent higher than the unit weight of 18.1650 grammes of the second series.

Thus the units of weights so far discovered in the Indus Valley Civilization, as systematically arranged and analysed, cannot but give us the impression of trained mathematical mind working behind their improvisation. Even in default of any document directly testifying to the mathematical activities in the period of First Urbanization, therefore, we are in possession of many circumstantial evidences indisputably indica-

31. *Ibid* 142-43.

ting the development of mathematical knowledge of the Harappans.

6. MATHEMATICAL INSTRUMENTS?

It will be relevant to mention here the discovery of an interesting article among the Indus ruins which many archaeologists are inclined to view as a mathematical instrument—probably a compass used for surveying purposes. We are indebted to S. R. Rao not only for its discovery at Lothal but also for first drawing our attention to its possible use or function. Here is how he puts all this :[32]

> Town-planning presupposes a careful survey of the land and measuring of angles for determining the alignments of streets, drains and houses. For this purpose an instrument made of shell was used at Lothal. It is a hollow cylinder with four slits on each of the two edges. When placed on a horizontal board it can be used almost as a compass in plane table survey for fixing the position of a distant object by viewing it through the slits in the margins. The lines so produced pass through the central point. If the opposite slits on one side are joined by cords they cut at right angles, and if all the cords passing through the slits on both the margins are drawn on the came plane as shown in Plate XXXII. B they intersect one another at the centre and the angles so formed by the eight lines measure exactly 45° each. Obviously this instrument must have been used in land-survey and for fixing alignment of streets and houses. Marshall considered similar objects found at Mohenjo-daro as personal ornaments, but they are too thick to serve as finger-rings and have too many slits to serve as pendants.

There may be scope for further discussion about the possible use of this apparently peculiar object. In the meanwhile it may be noted that serious archaeologists and scientists are inclined to view it as possibly connected with the mathematical activities in the Indus Valley Civilization. Deshpande, for example, observes that it "was probably used as a compass for measuring angles."[33] D. P. Agrawal endorses Rao's view of it having been a surveying instrument and adds, "Recent explorations have produced this instrument from Pabhumath and other sites of Saurashtra.[34]

32. S. R. Rao, in LIC 107.
33. M. N. Deshpande, in IJHS VI, 1. p. 11.
34. D. P. Agrawal, in Possehl's IA—NP 90.

7. ASTRONOMY IN FIRST URBANIZATION

To begin with, let us recapitulate here one point already mentioned. We began with Childe's understanding of "the Urban Revolution," who notes that one of the achievements of this revolution was the creation of exact and predictive sciences. In this connection, he mentions two sciences, namely mathematics and astronomy which were brought into being by the inherent requirements of the revolution. However, of the three primary centres of the urban revolution, only two—namely Egypt and Mesopotamia— have furnished the archaeologists with direct documentary evidences of the making of mathematics and astronomy. The third primary centre of the urban revolution, namely the Indus Valley Civilization, has not provided the archaeologists with similar documents. Nevertheless, as we have tried to argue, as far as mathematics is concerned, there are many circumstantial evidences which cannot be explained without the admission of the making of mathematics in this third primary centre of the urban revolution.

First, certain archaeological relics—ranging from the broken scales, the units of weights etc. to the magnificent brick-structures like the Mohenjo-daro bath, the granaries, the Lothal "dock-yard", residential quarters and the superb town-planning remain totally unexplained without the presumption of the development of mathematical knowledge. To these may also be added certain motives of decorative art specially on the potteries which suggest geometrical knowledge. We have already given some specimens of this.

Circumstantial evidences in the second form wanting us to trace the roots of classical Indian mathematics in the achievements of Harappan culture—on which we have tried to put special emphasis in our discussion—is bound to prove highly controversial. We have described it as based on the 'method of retrospective probing.' Broadly speaking, the method is as follows. We come across certain mathematical works as belonging to a period the technological and other peculiarities essentially presupposed by which do not at all agree with archaeologically ascertained facts. Nor does the theoretical temper forming the background of this mathematics agree with the essential ideas and attitudes of those to whom this mathematics

is customarily attributed. In such circumstances—and in view of the palpable absurdity of the assumption that the mathematics was codified *before* its creation—we felt obliged to move backwards in Indian history and see if there was any period which fully answered to the technological and other requirements presupposed by the making of this mathematics, and we came across such a period in the mature Harappan Culture. Hence we wanted to presume that this mathematics was created in that period though at the present stage of our research we are unaware of how its tradition was transmitted to the much later period and the conditions of its codification in the form in which it reaches us. This, in short, is the essence of what we have proposed to call the methodology of retrospective probing and it remains for us to see its relevance for the inference of scientific activities in other forms in the period of First Urbanization.

With this recapitulation of what we have argued so far, let us pass on to the question of the other exact and predictive science, namely astronomy, which Gordon Childe argues developed to meet the requirements of the Urban Revolution. And our question is : Is there any sufficiently sound ground to presume the making of astronomy in the third primary centre of the urban revolution ? Here, again, we are confronted with formidable problems. Notwithstanding the recent tendency of some scholars to read astronomical knowledge in the Indus "seals"—a tendency to which we shall presently return—the fact remains that we have no direct documentary data to prove it, not to speak of delineating the nature of this astronomical knowledge even admitting its making in the Mature Harappan culture.

In such circumstances, we are left to raise only two questions. First, are there real circumstantial evidences wanting—or even compelling—us to presume that astronomical knowledge did develop in the Indus Valley Civilization ? Secondly, how far does our method of retrospective probing help us to infer—or at least to guess—the development of astronomical knowledge during the period of First Urbanization ?

The first of the two questions is answered in very broad terms by one of our senior archaeologists, M. N. Deshpande, who starts from the obvious fact that "the entire civilization

flowered forth as a result of surplus argiculture economy."[35] With this point in mind, let us quote his observation[36] on the possible development of astronomical knowledge in Harappan Culture :

> As agriculture must have largely depended on the rains, the knowledge of seasons and a calendar cannot be ruled out. The regularity of the movement of the heavenly bodies could not have escaped the attention of the Harappans. The priest dominated political hierarchy postulated in respect of this civilization may have strengthened its position on this specialized knowledge. The priests may have kept accurate astronomical records and forecast celestial events and advised the farmers on the time of sowing, harvesting and perhaps the flooding of the rivers so as to forewarn them of the possible catastrophe, which in the end is supposed to have contributed to the destruction of Harappan cities. It is, however, not possible to say with certainty whether they followed the solar or the lunar calendar, though the meagre evidence at our disposal would suggest the adoption of the solar calendar, for the representation of the moon is conspicuous by its absence while a solar symbol is present in the form of painted motif on pottery and in the form of urus-like animal which according to Mackay may have been a solar deity with the head of the beast taking the place of the sixth ray. In the absence of depiction of the moon and stars Mackay had suggested that inhabitants of Indus valley—an agricultural people—did not pay that attention to stars which, according to Smith, is a distinguishing feature of the agrarian population. Such an inference would not hold ground if we consider the following facts : The Harappans must have possessed the knowledge of stars for, without it, it is difficult to account for the rigid north-south and east-west orientation of the streets and lanes. In the burials the bodies of the dead were oriented : head pointing to north and feet towards south. The identification of the pole-star for this purpose has to be credited to the Harappans. Besides, the depiction of a boat on one of the seals and a potsherd and the recent evidence of a dockyard at Lothal would definitely point that the Harappans were navigators and ships laden with goods plied along the western coast as far as Bahrein Islands and perhaps beyond. In the circumstances we may have to conclude that the Harappans possessed sufficient knowledge of astronomy involving angular measurements of heavenly bodies.

I am aware of the fact that many writers on the India Valley Civilization would resent more or less strongly to some assum-

35. M. N. Deshpande, in IJHS Vol. VI No. 1. 6.
36. *Ibid* 8-9.

ptions on which Deshpande's observations are based. There is, for example, literally a wilderness of conjectures today concerning the socio-political organisation of the Harappans; so his subscription to the postulate of the "priest dominated political hierarchy in respect of this civilization" is not likely to be smoothly accepted. At the present stage of our discussion, however, let us not digress into this controversy, though we shall be compelled to return later to it and shall see why many prominent features of the Indus Civilization remain unexplained without it and also the flimsiness of the other postulates proposed as alternatives to it. Nevertheless, it is not easy to question the main points of Deshpande. A civilization thriving on vast argicultural surplus cannot do without a developed calendrical system. And the development of a calendrical system is not conceivable without astronomical knowledge. This is part of common knowledge, which E. N. Fallaize sums up as follows. Astronomy is not "called for by the practical requirements of a population which lives chiefly by hunting. For an agricultural people, however, foreknowledge of the recurring seasons becomes essential, and it is necessary that some means should be found to mark the proper seasons for performing the operations to ensure the food supply."[37] If such be the essential need for a calendrical system—and therefore also of astronomy—even at the early stage of the development of agricultural technique, it would be too bold to imagine that the vast area under Harappan culture thriving basically on agricultural surplus could do without it, particularly when we remember that the Indus Valley Civilization was further confronted with the problem of flood and inundation of the rivers and therefore also the agricultural operations of the region required the know-how of predicting or anticipating these.

The other circumstantial evidences mentioned by Deshpande wanting us to presume astronomical knowledge in Harappan culture appear also to have substantial weight. Thus, for example, the accurate or near-accurate knowledge of north-south and east-west directions followed by the city-planners of the Indus Valley Civilization and also the burial custom of the Harappans implying the knowledge of cardinal directions could be possible on the basis of the identification of some "fixed

37. E. N. Fallaize, in ERE XII. 62.

star", just as in default of any archaeological evidence recovered so far suggesting the mariner's compass or its prototype, the navigational activities of Harappan traders following sea routes seem to suggest dependence on the konwledge in some form of the heavenly bodies.

All these are presumptions no doubt—presumptions that lead us at best to some sort of a vague assumption of astronomical knowledge in some form during the period of our First Urbanization. But are we supposed to leave the matter like that? Or is there any other way of moving towards a more substantial knowledge of the development of astronomy in the Indus Valley Civilization?

8. SPECIMEN OF WILD CONJECTURE: "GREAT BATH" AN ASTRONOMICAL OBSERVATORY?

In the absense of definite document, the archaeologists are often left to conjecture no doubt. At the same time, there should be some difference between a reasonable conjecture and a just wild one, with not even the semblance of real data supporting it. It is our misfortune that the extensive literature on the Indus Civilization is not without such wild conjectures. We shall mention here one example of this, because it professes to throw very important light on astronomy of the period under discussion. Nor can we just afford to ignore it, because the fact is that somehow it has found place in an otherwise very prestigious publication.

I have before me a very imposing volume with the title *Frontiers of Indus Civilization* edited by B. B. Lal and S. P. Gupta—both respected names among Indian archaeologists today. It contains contributions from eminent archaeologists of India and abroad and some of these contributions are of outstanding importance. But it also contains an article by Brij Bhusan Vij on "Linear Standard in the Indus Civilization". The most startling conclusion the author wants to arrive at in this is that the Great Bath of Mohenjo-daro was an astronomical observatory. As he puts it, "The 'great bath' of Mohenjo-daro was scientifically constructed to calculated dimensions, indicating the keen sense of mathematics and astronomy. This was therefore an important observatory, apart from being a 'community bathing|swimming pool.'"[38]

38. Brij Bhusan Vij in FIC 156.

The very idea of an important observatory being also a swimming pool may appear to be extraordinary, and it seems that the author himself is not serious about it. In the same article he observes, "The 'bath' can be interpreted to have been specifically constructed for use as a 'possible observatory' rather than a mere 'community swimming or bathing pool'."[39] He repeats, "The Great Bath at Mohenjo-daro was constructed to meet specific intention|requirement, possibly to make an astronomical observatory, and that it was not just a 'community swimming pool' ".[40] So the emphasis is obviously on its having been an astronomical observatory.

Such a view is startling, of course, and we are not aware of any other serious archaeologist suggesting such a possibility, notwithstanding the fact that the architectural skill and mathematical calculations evidently required for its construction cannot but be considered as an archaeological marvel. But had the Great Bath been an astronomical obseervatory—or, had our author been able even to adduce any really plausible consideration in favour of the hypothesis—the problem of the making of astronomy in the Indus Civilization would not have remained at a rather groping stage, as it is today. So the crucial question is : How far has our author been able to substantiate the possibility ?

Leaving aside some modern scientific jargons with which he begins the discourse, like the energy levels of the krypton .86 atoms and hyperfine frequency of Hydrogen etc.—the bearing of which on the Great Bath having been an astronomical observatory or not is obviously irrelevant—let us note what he has to say about the Bath itself. Referring to his own diagram, he observes :[41]

> ABCD represent the base plan of the 'great-bath' with its broader side BC—23 feet or 7.01 metre; and the diagonal AC—46 feet or 14.02 metre. If the standard diamensions of the bricks used during that age is accepted as 300 mm × 150 mm × 75 mm, it will be seen that the length, breadth and depth needed about 40, 24 and 8 'brick-lengths' respectively. A total of 61,444 such standard bricks would be needed to fill the volume of the 'great-bath'. This suggests that

39. *Ibid* 154.
40. *Ibid* 155.
41. *Ibid*.

the idea of a right-angled triangle, i.e. the Pythagorus (*sic!*) theorem, and hence *pi*/2 goes back to antiquity; at least to the Indus Valley Civilization.

To this he adds[42]:

The longer side, AB, thus worked to the measured dimension of 39.78 feet or 12.124 metres (i.e. 3 × 7.01 metre). Not only this, the depth of the 'great-bath' was very carefully chosen to represent an angle *pi*/18 between the base diagonal and the 'skew diagonal', i.e. the angle CAE in the figure. The measured height (from base upward) represents the linear distance 8 feet or 2.44 metre, which make Sine CAE – Sine *pi*/18 = 2.44/14.02 = 0.174 037 conforming the statement that Sine CAE = Sine 10° = 0.173 6 (from common log tables). Hence, the idea of angles and their application was definitely known in the antiquity of past India". [From these data] the author therefore, concludes: The Great-Bath at Mohenjo-daro was constructed to meet specific intention/requirement, possibly to make an astronomical observatory; and that it was not just a 'community swimming pool.'.

I have myself failed to see in all this anything substantial from the astronomical viewpoint specially as indicative of the Great Bath having been an astronomical observatory. However, not being an astronomer myself, I had the feeling that I might have overlooked or failed to understand something of genuine astronomical significance without which it is not easily conceivable how such an article could find place for itself in the imposing and prestigious publication. With appropriate humility, therefore, I passed on the article to two of my friends who are themselves astronomers and have very kindly agreed to advise me on astronomical matters in preparing the present study. They are Ramatosh Sarkar and Apurva Kumar Chakravarty. Both of them scrutinised the article and told me that from the astronomical point of view at any rate they could read nothing really substantial in the article itself. Whether the Harappans developed any astronomical science at all is a different question. As far as this is sought to be substantiated by the article under consideration and specially the startling claim that the Great Bath at Mohenjo-daro was actually an astronomical observatory, R. Sarkar fully agreed with A. K. Chakravarti and advised me to ignore this article altogether as sub-controversial.[43]

42. *Ibid.*
43. See Appendix.

I have mentioned all this only to emphasise one point. We are not obliged to impute importance to everything written about the Harappan Culture howsoever imposing—and even otherwise important—a volume may be in which it finds place, as is the *Frontiers of Indus Civilization*. Even completely baseless conjectures may creep into such volumes, somehow eluding the critical judgement of its responsible editors.

9. ASTRONOMY AND THE INDUS "SEALS"

Are we, then, left with nothing of the nature of real archaeological data indicating the making of astronomy in the Indus Civilization? A number of serious scholars both in India and abroad want us to answer the question in the negative. There is a growing tendency among them to see in the Indus "seals" indications of a calendrical system and other astronomical data.

We begin with an observation of Asko Parpola who has given us an excellent summary of this. Discarding the tendency of some scholars who "have proposed various Sanskrit solutions to the problem of the Indus script" on certain grounds,[44] Parpola has assumed that the language of the Indus people was presumably of Dravidian affinity—a presumption in favour of which Iravatham Mahadevan in his *Study of the Indus Script Through Bi-lingual Parallels*[45] has very strongly argued. Arguing on this presumption Parpola is inclined to agree with the Soviet scholars working on the Indus script who claim to read in the sign  "as *min* 'fish'=*min* 'star' and therefore the sign  as six stars, which is the "Old Tamil name of Pleiades, aru-min, 'six star' ".[46] Assuming this to be some sort of evidence for his view, Parpola proceeds to argue :[47]

44. Asko Parpola in EIP 167.
45. I. Mahadevan in Possehl's ACI 261ff.
46. Asko Parpola in EIP 178. I. Mahadevan TIS 717 : the fish sign alone occurs 381 times (p. 718) ; the sign of six lines occurs 38 times and the compound sign of fish with six lines occurs 16 times (p. 732). The inscription numbered 2128, e.g., contains this compound sign. (p. 61).
47. *Ibid.* 179.

The above mentioned interpretations of the fish signs agree with the factual information from later times. The names of planets and constellations read in the Indus texts are actually attested in historical documents and are of genuine Dravidian etymology. The fish signs which we read as planetary names make the most important group of those signs that we concluded from the contextual evidence to be probably god's name. The worship of such astral deities seems to have survived in the *navagraha* worship of later Hinduism ; in the Harappan religion the five planets proper seem to have represented gods who in later times emerged as leading Hindu deities : Brahma, Rudra/Skanda, Kala (Yama), Krsna and Balarama.

Like Father Heras (1953) and our Soviet colleagues (*Proto-Indica*: 1968, *Proto-Indica*: 1972) in their own ways, I have also followed up clues which the fish signs of the Indus script give by suggesting that ancient Indian astronomy and star lore may be largely of Harappan origin. Since the present book is intended for students of Indian archaeology, I want to conclude by referring to some important results, which in addition to giving further confirmation to the above hinted interpretations are of archaeological interest. While absent in the Avesta and the older books of the Rgveda (the latter composed on or soon after the arrival of the Rgvedic tribes to India), the names of the lunar asterisms (Sanskrit *naksatra*) appear in a complete list in *Atharvaveda*. It seems quite certain that the Aryans leatnt the naksatras in India. While such luni-solar calendars as that connected with the naksatras are not created by primitive or nomadic peoples (Nilsson, 1920), they form an essential element in all early urban civilizations (Steward, 1955 p. 194 ff). The date when the *naksatra* calendar was complied can be determined by means of astronomical evidence inherent in it : it was in all likelihood around the 24th century B.C. (Needham, 1959 p. 246 ff), which coincides with the peak of the Harappan urbanization, adding thus one more means for defining its chronology. The orientation of the Harappan cities according to the cardinal points, which could be accomplished by astronomical means only, is tangible evidence for Harappan practice of astronomy. The Dravidian origin of the *naksatras*, on the other hand, seems proved by the long unexplained word *b(h)ekura* or *ori* used as their appellation in the *Brahmana* texts, which appears to be of Dravidian etymology (cf. Tamil *vaikuru-mtn* and Burrow & Emeneau, 1961, nos. 4570, 608).

Two points in this observation are in need of clarification. First, about the team of Soviet scholars working on the Indus script, with which Parpola's own team is in substantial agreement. Secondly, about Parpola's reference to Needham's authority which is really based on many complex considerations, i.e. is not as simple as Parpola's own reference is likely to give us an impression.

As for the Soviet scholars, Parpola[48] himself explains :

> Only after the publication of our first preliminary report in 1969 we came to know the methods and results of a team of Soviet scholars who happened to start working on the Indus script simultaneously with us in 1964 (*Proto-Indica* : 1968). Headed by Yurij V. Knorozov, well known for his earlier computer work on the Mayan script, they, too have made use of the computer. Even otherwise our independent researches are in concord in several important respects. Soviet scholars have come to the same conclusion about the type of the Indus script, including the use of the rebus principle, attempted a division of the inscriptions into words, tried to identify grammatical elements, and to interpret individual signs from their contexts. Moreover, we agree also in considering the Indus language to be of Dravidian affinity.

Without trying to go into the methodology of the Soviet scholars, the full report of which is yet to reach us, we may quote here from a recent Soviet publication the general conclusions they are driving at. In *The Image of India : The Study of Ancient Indian Civilization in the USSR* by G. Bongard-Levin and A. Vigasin we read :[49]

> Research into proto-Indian writing enabled Soviet scholars to reveal certain features of the religious-mythological concepts of the inhabitants of Harappan settlements, first and foremost various kinds of cult objects (anthropomorphic, zoomorphic, sacred trees, "deified vessels"), but the most important was to establish the general character of proto-Indian cosmogonic concepts and the calendar system.
>
> Soviet scholars came to the conclusion that the inhabitants of Harappan settlements divided the year into three large and six small seasons. The symbols of the small seasons were representations of animals, the aurochs (the unicorn ; it was also the symbol of the year), goat, tiger, shorthorned aurochs and the bull. The zoomorphic symbols also, apparently, denoted the large seasons : the season of overflowing of rivers was "transmitted" by a representation of the crocodile ; the year began with the season of the aurochs ; the zebu and the scorpion symbolished the vernal and autumnal equinoxes. The sixty-year cycle (the cycle of Jupiter), which was followed in ancient India also in a later period, obviously arose in the Harappan era. The "Proto-Indians" divided this cycle into five twelve-year periods.

It is obviously premature for us to comment on this. But it may be incidentally mentioned here that already there is a

48. *Ib.* 178.
49. G. Bongard-Levin and A. Vigasin 194.

tendency among some scholars to trace the source or origin of the alphabet to the names of the heavenly bodies. As J. Needham sums it up, "Moran (H. A. Moran, *The Alphabet and the Ancient Calendar Signs*, Calif. 1953) has sought to show that the letters of the earliest alphabets were derived from the symbols of the 28 lunar mansions, and thus to explain the fact that most sets of alphabetic letters have from 25 to 30 components (D. Diringer, *The Alphabet : a Key to the History of Mankind*, N. Y. 1948). A full phonetic alphabet needs 46. The thesis is original, the hypothesis even seductive, but the presentation marred by too much special pleading".[50] There is thus some *prima facie* support for those scholars in India and abroad to read in the Indus "seals" some calendrical|astronomical sings, though it is needless to add that what is inferred from the Indus signs will be convincing to the extent to which it coheres with the other evidences, inclusive of archaeological and—if possible—literary ones.

Secondly, as we have already said, there is another point requiring clarification about the general observation of Parpola we have quoted. It is concerning his mention of Needham's authority about the dating of the *naksatra* system, which, as is well-known, has a very important place in Indian astronomy. To repeat what Parpola says : "The date when the *naksatra* calendar was complied can be determined by means of the astronomical evidence inherent in it ; it was in all likelihood the 24th Century B.C. (Needham, 1959, pp. 246 ff)." Lest it gives the wrong impression that Needham himself arrives at this date, it may be useful for our purpose to be clearer about this point.

Not that Needham does not discuss the *naksatra* system, usually rendered as the system of "lunar mansions" or "lunar zodiac". But the real reason for this is his primary interest in the history of astronomy in China, where we come across a strikingly similar system, which is called that of *hsiu*. We also come across an Arabic parallel of it, called the system of *al-manazil*. Hence, there is a good deal of controversy among the scholars about the exact origin of these strikingly similar systems. As Needham[51] sums up :

50. Needham SCC III. 239 note-g.
51. *Ibid*. III. 252-53.

And this is where we come to the problem which has caused so much controversy, namely, the relation of the Indian *naksatra* and Arabic *al-manazil*, 'moon-stations' to the Chinese *hsiu*. First brought to the attention of Western scholars by Colebrooke in 1807, many lists of the *naksatra* are available, while Biot analysed the data on them which al-Biruni had collected in the + 11th century. Lists of the Arabic *al-manazil* will be found in Higgins and others. They were certainly pre-Koranic, and the Hebrews knew them as the *mazzaloth*, while they even got into Coptic (Chatley). Iranian versions of the moon-stations are also known. The earliest reference outside Asia is in a Greek papyrus of the + 4th century analysed by Weinstock.

The common origin of the three chief systems (Chinese, Indian and Arab) can hardly, be doubted, but the problem of which was the oldest remains. That of the *manazil* is not a competitor, but the other two have elicited from time to time remarkable displays of vicarious chauvinism on the part of indianists and sinologists.

Needham himself seems to attach much importance to the view of Biot, though also differing with him rather strongly on an important point. By analysing the Chinese calendrical system of the "lunar mansions", Biot tried to establish two main points. First, from the internal evidence of this calendrical system, it can be inferred that it originated in the 24th century B.C.—or, to be more precise in 2357 B.C.[52] Secondly, the actual place where this system originally developed was China. Needham seems to be in favour of the first point and scrap the second. Referring to the paper "On the origin of the Twentyeight Mansions in Astronomy" (*Popular Astronomy*, 1947, pp. 62 ff.) by Chu Kho-Chen, who wants to support Biot's second point and summarises most of the evidences currently put forward for the view that already in the third millennium B.C. the *hsiu* system came into being in China, Needham comments rather sharply, "The great difficulty about this is that all the archaeological and literary evidence is against so early a date."[53] Discarding the theory of the Chinese origin of this system, Needham himself is inclined to think "that it may be possible to find a common origin in Babylonian astronomy for all 'moon-station' systems."[54] Such

52. *Ibid.* III. 177, note-c.
53. *Ibid.* III. 249.
54. *Ibid.* III. 254.

a view was first suggested by A. Weber in 1852;[55] it was as strongly supported in 1909 by H. Oldenberg[56] though vigorously contested by many scholars.[57]

The origin of the *naksatra* system being still highly controversial, we have found it preferable to discuss this separately in the Appendices. Biot's view, viz. it dates back roughly to the 24th century B.C., is reasserted by my advisers on astronomy from evidence of *Brahmana* texts. For the present we may mention only some other points.

Admitting Biot's dating of the formation of the original nucleus of the system and encouraged by the recent tendency of reading some of the *naksatra* names in the Indus "seals", it may not be *prima facie* impossible to think that the progress of our knowledge of the Indus civilization may in the future reach a stage showing the prevalence of the *naksatra* system (or something closely resembling it) already, during the period of our First Urbanization. Admitting this,—and we shall presently see some more substantial evidences supporting its possibility—we have to accept Parpola's claim that the Vedic peoples—originally unaware of any astronomical knowledge worth its name—eventually acquired (and used scraps of it) from the tradition coming down from the Harappan period.

10. METHOD OF RETROSPECTIVE PROBING: CHRONOLOGICAL POINTER

While discussing the mathematical knowledge contained in the *Sulva-sutra*-s, we have already mentioned and depended upon what we have called the method of retrospective probing. The assumption on which it is based may be briefly reiterated. When we come across some materials codified in the literature of a period which, on various considerations, has got to be considered as later than the data itself, there remains the possibility of moving background to some period in which such

55. A. Weber's *History of Indian Literature* (first German Edition, 1852, p. 21). and the first of his *Essays on the Nakshatras*, 1860, passim.
56. H. Oldenberg, in JRAS 1909, 1095 ff.
57. See G. Thibaut, in JASB 1894, 144-163; W.D. Whitney, in JAOS 1864, 1-94.

data is logically conceivable. Hence the presumption is that though the data come down to us as forming part of the literature of a later period their origin is to be traced to the earlier period from which they are somehow inherited.

Though without formulating this method and certainly not accepting its real implication, H. Jacobi[58] and B.G. Tilak[59] independently of each other followed it unconsciously, as it were, and opened for us the possibility of determining the antiquity of Indian astronomy. What they did was to recover from the Vedic literature certain references to basically astronomical observations. These observations, analysed according to the modern methods of astronomical calculations, want us to go back to hoary antiquity—to the third or fourth millennium B.C., though, according to Tilak, the period could be even earlier. From this, they argued straightway that the date of the Vedic literature itself is to be pushed to the same antiquity, without hesitating at all to *assume that the actual date of the observation must be the same as that of the literature in which it is referred to or mentioned in some form.* But such an assumption is not really obligatory. On the contrary the possibility remains that certain traditions actually come down from a hoary antiquity and accepted as authentic without verification by later writers. In the case of the Vedic literature—and more particularly in the early *Samhita*-s and the comparatively later *Brahmana*-s—such a possibility becomes quite strong sepcially because of a number of reasons.

First, the astronomical data found in the *Samhita*-s and *Brahmana*-s are so desultory—and what is wrose, so deeply embedded in discussions concerning ritual trivialities and theological disputations—that it requires much more than average proficiency in Vedic literature to locate these and disentangle the astronomical data from the framework of highly quaint logic seeking support from these for their rituals or

58. H. Jacobi, in *Festgruss on Rudolf von Roth*, Stuttgart, 1893, 68-73; in NGWG, 1894, 105-116; OC 1894, I. 103-108 cf. also H. Jacobi in JRAS 1909, 721-726.

59. B.G. Tilak *The Orion*, Bombay, 1893; for a brief review of the controversies over the views of Jacobi and Tilak, see Winternitz I. 293 ff., and for the different views expressed on the point see specially note 1, Winternitz, I. 295.

somehow connecting their own rituals with these data. It is indeed difficult to imagine people with any genuine interest in astronomy talking of astronomy in such a casual manner and using astronomical knowledge for this kind of mystery-mongering. On the contrary, it is quite conceivable that the priests whom we meet in the *Yajurveda* and the *Brahmana*-s—interested as they were above all in their *daksina* or sacrificial fee—could be trying to use every scrap of astronomical data coming down from a hoary past to add to their sacrificial rituals an awe-inspiring appearance *without bothering to verify these* astronomical data by the direct observations. We have added the last clause, because as we shall presently see the astronomical references in the *Brahmana*-s etc. do not really fit in with spatial or temporal contexts of these texts, though these can be taken as pointers to regions other than those of the Vedic settlements proper and to a period much anterior to that of the *Brahmana*-s.

Secondly,—and this is really a much more serious reason why the conclusions of Tilak and Jacobi could not and did not have much impact on Vedic scholarship,—there are other and sounder ways of dating the Vedic literature and these prevent us from pushing back the date of the literature to the hoary antiquity, as Jacobi and Tilak proposed. It is evidently outside the scope of our present discussion to try to enter into the technicalities of the question of determining the date of the Vedic literature. What is possible for us here is to quote some authoritative opinions expressed on the question. R.S. Sharma observes. "The French scholar Louis Renou, a life-long student of the Vedic texts accepted the view of Max Muller that the Aryans appeared in India around the fifteenth and sixteenth centuries B.C. and placed the hymns of the *Rg Veda* around this date."[60] The *Yajurveda* texts are much later. As Sharma continues, "On the present showing, the use of iron in the Indo-Gangetic divide and the Upper Gangetic basin, in which the *Yajus* texts and the *Brahmana*-s and *Upanisad*-s were compiled, cannot be taken back earlier than 1000 B.C., for this metal is known to several texts. Renou thinks that the *Brahmana*-s should be placed between the tenth and seventh centuries B.C."[61]

60. R.S. Sharma, MCSFAI 168.
61. *Ibid.* 169.

Accepting these chronological as well as geographical views, we may first briefly discuss some of the astronomical data to be found in the *Brahamana*-s and in texts usually accepted as belonging to this tradition. The main purpose of our discussion being only to show the possibility of the making of astronomy during the period of our First Urbanization, we propose to select here from the Vedic literature primarily two data, which, though without agreeing with the time-space contexts of the Vedic literature, can reasonably be accepted as pointers to the Indus Valley Civilization. After discussing these, we shall return to the views of Jacobi and Tilak, mainly to show the somewhat necessary limitation of their time which appears to have been at least one reason that obliged them to push back the dating of the Vedic literature to an unacceptable antiquity.

One of these astronomical data is concerning a certain asterism or *naksatra* called Krttikas, with which incidentally all the lists of the 27 *naksutra*-s mentioned in Book XIX of the *Atharvaveda* as well as the different recensions of the *Yajurveda* like the *Taittiriya-Samhita*, *Kathaka-Samhita* and *Maitrayani-Samhita* begin, though of course the last mentioned text mentions 28 *naksatra*-s by way of adding a certain Abhijit to it. All the important Vedic data about the *naksatra*-s as well as the views of the modern scholars on these, are to be found in the *Vedic Index* by Macdonell and Keith though strangely enough the French scientist Biot—a predecessor and in some sense preceptor of Louis Pasteur—is mentioned here as a Chinese scholar![62]

Jacobi argued that the Krttikas were counted the first *naksatra* because it then coincided with the vernal equinox; from this he wanted to conclude that the Vedic culture was already in existence by 3000-2000 B.C. when this astronomical phenomenon did occur. How far this argument still holds good is a separate question. But certain other things said about the Krttikas have obvious chronological implications.

Such a statement is to be found in *Satapatha Brahmana* ii.1.2.1-5.[63] As is only to be expected in the *Brahmana* literature, the statement forms part of a theological controversy. The controversy is concerning the setting up of the two fires—

62. Macdonall and Keith VI. I. 409/430.
63. Tr. Eggeling SBE XII. pp. 282-3.

called Garhapatya and Ahavaniya—under the asterism considered most desirable for the purpose. Two views are mentioned in this connection : 1) that the fires are to be set up under the Krttikas and 2) these are not to be set up under the Krttikas. The ground adduced for the second view is that originally the Krttikas were the wives of the Seven Rsis (Saptarsi = Ursa Major or the Wain) and since the latter rise in the north and the Krttikas in the east they were precluded from having intercourse with their husbands, and the same will result from the act of setting up of the two fires under the Krttikas. The authority in our *Satapatha Brahmana*, however, rejects this view and offers a series of arguments in favour of the recommendation of setting up the two fires under the Krttikas. These arguments are :

(a) The Krttikas are Agni's asterisms, so that if he sets up his fires under Agni's asterisms, he will bring about a correspondence between the fires and Agni's asterisms.

(b) While the other lunar asterisms consist of one, two, three or four stars, the Krttikas are the most numerous of asterisms (consisting of seven, or according to others, six stars) ; hence he, by setting up the fires under the Krttikas, obtains an abundance.

(c) These (i.e. the Krttikas) do not move away from the eastern quarter whilst the other asterisms do move from the eastern quarter ; thus his two fires are established in the eastern quarter.

The general framework of the theological disputation concerning the desirability or otherwise of placing the sacrificial fires under the Krttikas can obviously have no interest for the historians of science. Nevertheless, one point mentioned in this connection cannot be ignored or overlooked. It is the statement that the Krttikas do not move away from the eastern quarter, while the other asterisms do move from the eastern quarter. Our text is quite firm on this point : *eta ha vai pracyai diso na cyavante|sarvani ha va anyani naksatrani pracyai disas cyavante.*[64] Commenting on the words *pracyai na cyavante* (does not swerve from the east) Sayana obser-

64. *Sat. Br.* ii. 1.2.3.
65. P. C. Sengupta, in IHQ 1934, 536.

ves *niyamena suddha-pracyam eva udyanti* (invariably rises in the exact east). Following this P. C. Sengupta seems to be justified in saying, "This means that the Krttikas rose exactly at the east"[65] and this is viewed as a distinctive peculiarity of the asterism, i.e. as contrasted with the others. Eggeling also in his translation of the *Satapatha Brahmana* accepts such an understanding and writes, "The Seven Rsis rise in the north and they (the Krttikas) in the east."[66]

Accepting this meaning of the statement we have a very interesting astronomical information here. It is the observation of the fact of the Krttikas rising exactly at the east. Depending on astronomical works like the (modern) *Surya-siddhanta*, eminent Indologists like Burgess, Whitney and others identify the Krttikas with the asterism Pleiades, with *Eta* Tauri as its determinative star. If, therefore, we take this as an actual piece of observation (somehow) codified in the *Satapatha Brahmana*, it is possible for the astronomer-mathematicians to calculate and determine the date when this observation actually occurred. So I passed on this data to the astronomer-mathematicians advising me on the present work, namely, Apurva Kumar Chakravarty and Ramatosh Sarkar, and both of them arrived at the view that the astronomical observation under consideration wants to take us back to the middle of the third millennium B.C.—a result agreeing with the calculations of P. C. Sengupta.

To avoid digression into the technicalities of the calculations involved, I have preferred to use their discussions of the questions in the form of separate Appendices. For the purpose of our present discussion we shall mention here only a few points based on these.

The *Eta* Tauri can rise exactly in the east only when its declination is nil, or, as Sarkar shows, when its celestial longitude is zero and celestial latitude is negligible, i.e. roughly coinciding with the vernal equinox.

But the celestial longitude of the star in 1985 is 59° 47′ 24′.

Calculating on the basis of the precessional rate of 1° for every 72 years on an average, we have to go back to 2334 B.C. to reach the period when the celestial longitude of *Eta* Tauri would have been thus nil.

66. Eggeling in SBE XII. 283.

Calculating on the same basis, however, by 1000 B.C.—i.e. roughly the time beyond which the *Satapatha Brahmana* (with all its inner complexities) cannot be pushed back by responsible Vedic scholars—the celestial longtitude of *Eta* Tauri would have been 18° 28′ 12″.

All this means that the statement that the Krttikas rise exactly in the east could by no means be based on an actual observation of the period of the *Satapatha Brahmana* though the date of the event amazingly coincides with the peak period of the Harappan culture when, therefore, it could form part of real astronomical observations.

Could it, then, be that the statement under consideration, viz. that the Krttikas rise exactly in the east, actually formed part of the astronomical knowledge which really developed in the Harappan Culture and it "somehow" came down to the authors|compilers of the *Satapatha Brahmana* who accepted and codified it without bothering to verify it by actual observation just to add some weight—or, perhaps better, some mysterious awe—to their ritual prescriptions? Astronomical contents developing in a very ancient period receiving condification centuries later is not *prima facie* impossible. Here is an example we quote from Needham : "Assyriologists have long been familiar with a number of cuneiform tablets which were preserved in the library of King Assurbanipal (Ashur-bani-apli, 668 B.C. to 626 B.C.) at Nineveh, but which date as to contents from the late 2nd millennium B.C."[67] These tablets could, of course, belong to an earlier date. But the point is that the preservation of these in the royal library of much later date presumably meant that importance was still being attached to these in the comparatively later period when their astronomical contents must have substantially changed to tally with actual observations of the time of their careful preservation. Thus, acceptance of ancient data without fresh verification is not *prima facie* impossible. In any case, the *Satapatha Brahmana* shows that what the priests say about the Krttikas has not even the semblance of interest in actual observation of the phenomenon referred to : it is just mentioned as one of the many grounds favouring the view that the sacrificial fires were to be placed in the east, because the Krttikas—un-

67. Needham SCC, III 254-56.

like the other asterisms—rise in the east, without in the least bothering to observe that in their time the Krttikas did not *actually* rise exactly in the east. To the astronomers of the Harappan Culture, it was presumably different. During their time the Krttikas did rise exactly in the east and in all likelihood they actually observed it.

The admission of such a possibility, seems to indicate some presumptions of far reaching consequences. Evidently enough, persons interested in astronomical observations could not be satisfied in noting a single phenomenon in its isolation like the rising of the Krttikas, specially when it is added that this is a distinctive peculiarity of the Krttikas as contrasted with the other asterisms. On the contrary, the presumption is that the observation under consideration formed part of a system of astronomy, only scraps of which reached the Vedic priests who wanted to use these in connection with their sacrificial cults. One is thus tempted to raise the question : Could it be that the entire *naksatra* system—which we find referred to in Book XIX of the *Atharvaveda* and the different recensions of the *Yajurveda* without ever giving us the impression of any systematic interest in astronomical observations and always arbitrarily connected with nothing more than theological trivialities—had its real roots in the astronomy of the Harappan Culture ?

The question is, of course, highly complex and too many views are already expressed on the astronomical data in the Vedic literature to allow any discussion of the subject without entering into a good deal of polemics. At the present stage of our discussion we may as well avoid it and to have separate appendices for the more technical details. Instead of that we shall note here only a few points of obvious interest.

The refences to the *nakasatra*-s apart, we come across in the Vedic literature certain statements with obvious astronomical interest. Among the modern scholars, Tilak and Jacobi are the more eminent ones who first put much emphasis on these. Rejecting the tendency of brushing these off as sheer priestly nonsense, they took these as genuine pieces of observation. Applying the modern methods of calculating the possible dates when such astronomical data could form part of actual observation, they felt compelled to go back to an early antiquity —far beyond the time usually admitted by the Vedic scholars

as that of the composition of Vedic literature. From this they argued that the dating of this literature was in need of serious revision, or that the actual date of the making of this literature was to be pushed back to a great antiquity. Though some of the prominent scholars like Valle Poussin, Barth and Winternitz felt that it will be wrong to ignore "Jacobi's great chronological argument"[68] the majority of Vedic scholars wanted to reject this as just absurd. Not that the astronomical data —and these as pointers to much antiquity—were necessarily questioned. What was questioned was the argument that since such data are found recorded in the Vedic literature, these are to be taken as indicative of the date of the literature itself. What is ignored is the possibility that the date of observation of certain phenomenon is not necessarily the same as that of their codification, that the tradition of certain facts of observation may come down from a hoary antiquity though only to be used in codified form at a much later period by people with scanty enthusiasm for direct observation and therefore without the need felt for verifying the data with direct observation of their own. This was perhaps not so in the case of the priests during the First Urbanization, when as "organisers of production" they had to take actual astronomical observations with much seriousness. Cut off from this social function, the Vedic priests became on the whole social parasites subsisting only on the *daksina*-s or sacrifical fees received from the rich patrons financing the sacrifices. Accordingly, it was only natural for them to develop a different theoretical temper, which, as we have already noted, was basically opposed to the spirit of direct observation, inasmuch as this went against the tendency of deliberate mystification : *paroksa-priyah iva hi devah, pratyaksa-dvisah*. At the same time, certain scraps of knowledge about the celestial phenomena forming part of ancient astronomical lore could somehow come down to them and could be effectively used by them to add grandeur to their sacrificial cults, which, therefore, they could as well graft in their own literature. Thus in short, there are grounds to think that the actual date of observation of the astronomical phenomena mentioned in the Vedic literature may be much more ancient than their mention or codification in the Vedic literature. From

68. See Jacobi in JRAS 1909 721.

this point of view, the dating of the Vedic literature from the astronomical data contained in these may be more or less fallacious.

At the same time, we have to note a somewhat obligatory limitation of the conditions under which Tilak and Jacobi had to work. During their time nothing was known about Indian Culture pre-dating the Vedas; for them the Vedas were necessarily the starting point of understanding Indian culture. In short there was nothing for them on the basis of which to think that certain astronomical data coming down from the pre-Vedic period could somehow find place in the Veda.

It is interesting to note that Jacobi understood this limitation, though in his own way. In 1909, he said that if "we were quite sure that Vedic culture was not older than 1200 or 1500 B.C." we would be obliged to seek other explanations of the astronomical data contained in these. However, referring to the usually accepted date of the Vedas he added :[69]

> As long as this fact remains in suspense, either my arguments or these three subversive interpretations given to them by my opponents will appear plausible in accordance with the estimated age which critics assign to Vedic culture. When the new theory on the antiquity of the Veda was first discussed, I made this same statement to Mr. Tilak, who wished to enter upon a campaign against all opponents. I told him that the discussion would have no definite result *unless excavations in ancient sites in India should bring forth unmistakable evidence of the enormous antiquity of Indian civilization.*

Dramatically enough, hardly within two decades when Jacobi wrote this, the archaeologists' spade did prove the enormous antiquity of Indian culture. But it also relieved the scholars from the earlier but somewhat necessary limitation of equating the antiquity of Indian culture with that of the Vedic culture. Thus scraps of astronomical data that found place in the Vedic literature remained. So also the possible date of their actual observation. However, it became a chronological pointer to the Indus Civilization and not to Vedic Civilization.

We have noted here only one example of this. The Krttikas rise exactly in the east, asserts the *Satapatha Brahmana.* Though today they do not rise exactly in the east—and though even during the period of the *Satapatha Brahmana* they did not

69. *Ibid* 722, emphasis added.

rise exactly in the east—they did so during the peak period of the Harappan Culture, which moreover, based as it was on vast agricultural surplus, did need an astronomical-calendrical system, and therefore, also required the observation of the heavenly bodies as accurately as was possible in those days.

11. ARBITRARINESS OF THE INTEREST IN ASTRONOMY OF VEDIC PRIESTS

We have thus seen that there are some astronomical data recorded in the comparatively later Vedic literature that cannot be based on actual observation during the time of the composition or compilation of these texts. On the contrary, depending on mathematical-astronomical calculations we are led to accept the view that the actual observation on which these are based chronologically agrees with that of the Harappan period. We are inclined to accept these as chronological pointers to the making of astronomy during the period of our First Urbanization. We are inclined to presume further that though in the comparatively later Vedic literature, such propositions with astronomical interest are extremely desultory—mentioned here and there in the context of sacrifical rituals without showing any intrinsic connection of these with the sacrifices—there is no reason that the astronomical propositions recorded in these texts were originally only a bundle of stray observations. On the contrary the presumption is that these originally formed part of a coherent astronomical system, only fragments of which came down to the Vedic priests or were sought to be used by them for adding some kind of aura to their sacrificial craft. In substantiation of this argument we shall mention here only one example of how casual had been the astronomical interest of the Vedic priests.

In the *Satapatha Brahmana*, just after mentioning certain consideration for the desirability of setting up the sacrificial fires under the Krttikas—one of these being that the Krttikas rise in the east—the text passes on to mention various other *naksatra*-s or asterisms under which the same fires could be placed, offering arguments in favour of each, none with any astronomical interest. Thus :[70]

70. *Sat. Br.* ii. 1.2.6-13.

He may also set up his fires under (the asterism of) Rohini. For under Rohini it was that Prajajati when desirous of progeny, set up his fires...

He may also set up his fires under (the asterism of) Mrgasirsa. For Mrgasirsa, indeed is the head of Prajapati; and the head (*siras*) means excellence (*sri*); for the head does indeed mean excellence; hence they say of him who is the most excellent (*srestha*) of a community, that he is the head of a community....

He may also set up his fires under the Phalgunis. They, the Phalgunis, are, Indra's asterism, and even correspond to him in name; for indeed Indra is also called Arjuna this being his mystic name, and they (the Phalgunis) are also called Arjunis....

Let him set up his fires under the asterism Hasta whoever should wish that (presents) should be offered to him: then indeed (that will take place) forthwith; for whatever is offered with the hand (*hasta*), that indeed is given to him.

He may also set up his fires under Citra....

So from the viewpoint of the Vedic priests, the recommendation of setting up the fires under the Krttikas is not to be taken with a great deal of seriousness and so also the astronomical consideration mentioned in favour of it. There are various other alternatives to it based on alternative considerations, which, from the priestly viewpoint at any rate, are equally sound. What is indisputable about this discourse is that certain names of the asterisms came down to the priests of the *Satapatha Brahmana* and they somehow tried to connect these with their sacrificial cult. Indeed the discourse read as a whole—specially its concluding portion—seems to give us the impression that, though aware of these *naksatra* names, they were little concerned with understanding what these actually were. They suggested for the word the absurd origin from the sense of "powerlessness" and even went to the extent of imagining that the sun was the best or most desirable or most powerful of the *naksatra*-s! Before imputing any genuine astronomical interest to the Vedic priests we have therefore to take note of the concluding portion of the discourse which reads as follows:[71]

Originally these (*naksatras*) were so many different powers (*ksatra*), just as that sun yonder. But as soon as he rose, he took from them (*a-da*) their energy, their power; therefore he (the sun) is called Aditya, because he took from them their energy, their power.

71. *Ibid* ii. 1.2. 18-19.

The gods then said, 'They who have been powers, shall no longer (*na*) be powers (*ksatra*).' Hence the powerlessness (*na-ksatratvam*) of the *naksatras*. For this reason also one need only take the sun for one's *naksatra* (star), since he took away from them their enregy, their power. But if he (the sacrificer) should nevertheless be desirous of having a *naksatra* (under which to set up his fires), then assuredly that sun is a faultless *naksatra* for him; and through that auspicious day (marked by the rising and setting of the sun) he should endeavour to obtain the benefits of whichever of those asterisms he might desire. Let him therefore take the sun alone for his *naksatra*.

Thus whatever expectation in the astronomical interest of the Vedic priests might have been aroused in us by the statement that the Krttikas rise in the east is washed away by this almost total fantasy about the *naksatra*-s with which the discourse concludes. Apparently, the statement about the Krttikas that we read in the *Satapatha Brahmana* came down to the priests from some other source.

That the astronomical scraps in the priestly literature were borrowed from other peoples whom the Vedic priests considered as aliens and opponents seems to be faintly suggested by the *Taittiriya Brahmana*[72] which refers to a class of *asura*-s named *kalakajna*-s. Since *kalakajna* literally means 'the knowers of time', it may not be totally impermissible to read in it the suggestion of conversance with calendrical science. If so, the mention of them as *asura*-s is significant, for in the Vedic literature it is one of the typical words referring to the rivals and aliens—the most outstanding opponents of the gods. It will no doubt be a mark of impermissible haste to jump at the conclusion only from this evidence that we have here a reference to the Harappans with their calendrical system, for there is a good deal of controversy among the modern scholars about the actual people referred to in the Vedic literature as the *asura*-s. At the same time it may be another error to ignore completely the suggestion of the *Taittiriya Brahmana* that in ancient times there were *kalakajna*-s—presumably astronomers or experts in the calendrical calculations and interestingly enough, they belonged outside the circle of the Vedic peoples themselves—in fact considered as the aliens and

opponents of the Aryans so-called. From the scraps of astronomical data recorded in the Vedic literature which, chronologically speaking, are pointers to the period of the Harappan Culture, it may be a mark of hasty historiography to dismiss outright the possibility of these *kalakajna*-s having been the astronomers of the Harappan period.

12. METHOD OF RETROSPECTIVE PROBING GEOGRAPHICAL POINTER

If the later Vedic literature contains astronomical data which, when analysed, appear to be chronological pointers to the Harappan period, there are also data in the same literature which appear to be geographical pointers to the Harappan region as the place of astronomy in its making. We shall concentrate here mainly on one of these. It is to be found in *Vedanga Jyotisa*, literally 'astronomy as a limb of the Vedas or Vedic studies'.

Vedanga Jyotisa is a brief text that have come down to us in two versions—one claiming to belong to the tradition of the *Rgveda* and the other to that of the *Yajurveda*. The former is called *Arca-jyotisam* and the latter *Yajusa-jyotisam*. The text is very brief : in the printed edition we propose to follow here,[73] the first contains thirtysix verses and the second fortyfive. In both versions, the language used is classical Sanskrit, which is now current and hence from this viewpoint the work cannot be very ancient. But that is no index to the astronomical contents of the work, because the author|authors of both its versions claim that they simply present the views of a certain ancient authority called Lagadha[74]—a circumstance which accounts for the basic similarity in the astronomical content of the two versions. We have really nothing that can be considered as historical knowledge about this Lagadha, beyond perhaps the bare fact that the astronomical views he stood for is traceable to considerable antiquity. There is a tendency among the modern scholars to determine the date of

73. *Vedangu Jyotisam* ed. S. C. Bhattacharyya, Calcutta, 1974.
74. RV-J. 2 ; VJ-Y 44. Interestingly the name appears to be quite peculiar and it seems that it is not Sanskritic at all. We are aware of no scholar throwing light on this peculiar name.

Lagadha from certain astronomical data recorded in the text. As T. S. Kuppanna Sastry has recently claimed :[75]

> Verses 6, 7 and 8 of the Yajur Vedanga Jyotisa (Y-VJ) show that at the time of Lagadha the winter solstice was at the beginning of the asterism Sravistha (Delphini) segment and that the summer solstice was at the mid-point of the Aslesa segment. It can be seen that this is the same as was alluded to by Varahamihira in his *Pancasiddhantika* and *Brahatsamhita*. Since VM (Varahamihira) has stated that in his own time the summer solstice was at Punarvasu $\frac{3}{4}$, and the winter solstice at Uttarasadha $\frac{1}{4}$, there had been a precession of $1\frac{3}{4}$ stellar segments, i.e. 23° 20″. From this we can compute that Lagadha's time was $72 \times 23\frac{1}{3} = 1680$ years earlier than VM's time (*c.* A.D. 530), i.e. *c.* 1150 B.C. If, instead of the segment, the group itself is meant, which is about 3° within it, Lagadha's time would be c. 1370 B.C.

Admitting the accuracy of the observation of the phenomenon under discussion and admitting further that the actual observation is to be attributed to Lagadha himself, we have to admit that he lived roughly in the 14th century B.C.—i.e. in a period shortly following the end of the Mature Harappan Culture when, in the post-Harappan sites excavated recently by the archaeologists much of the traits of the Harappan Culture was still alive, and in any case, a period ante-dating by several centuries the making of the priestly literature of the Vedic people—the *Yajurveda* and the *Brahmanas*. This by itself casts doubt on the usual assumption that the *Vedanga Jyotisa* embodies an astronomical system evolved by the Vedic priests to meet the requirements of their priest-craft. Whitney strongly argues that this Jyotisa has no "relation to the Vedic ceremonial".[76] Besides, the possibility of the *Vedanga Jyotisa* incorporating into its astronomical system ideas coming down from a remote past cannot be totally ruled out, specially in view of the modern scholars failing to read in it a clearly consistent astronomical system: much of this brief text remains obscure for us and, as Thibaut has very convincingly shown, these remained obscure even to the most famous commentator

75. T. S. K. Sastry, in IJHS Vol. 19, No. 3, Suppl. 1984, p. 13; For discussion of the date of the observation under consideration, see also Pillai, *Indian Ephemeris* Vol. I, pt. i. 444-45.

76. Whitney OLS. Second Series. 384.

of it, namely Somakara, who, therefore, felt obliged to suggest fanciful meaning to many of its verses.[77]

As for the antiquity of the astronomical contents of the *Vedanga Jyotisa,* it may not be irrelevant here to mention another point. Varahamihira (*c.* A.D. 530) in his work 'the five astronomical systems' or the *Pancasiddhantika,* begins with an account of what he calls *Pitamaha Siddhanta* or the astronomical system of the grandfathers—evidently a figurative way of indicating its hoary antiquity. Compared to the other systems of astronomy discussed by him, this is considered by Varahamihira as crude and undeveloped, and hence he gives very meagre information about it.[78] But the interesting point is that Thibaut, comparing these information with some of those of the *Vedanga Jyotisa* feels "that the astronomical book quoted by Varahamihira as *Pitamaha Siddhanta* must have been either the Jyotisa itself or a work very much like it."[79] We may perhaps have in this a clue to the apparent obscurity—often amounting to almost illegibility—of the extant versions of the *Vedanga Jyotisa,* because, as we have already seen, the classical Sanskrit used in the texts indicates that these must have been written or codified in a period much later than that of the formation of the astronomical core of the *Vedanga Jyotisa,* and, as such, much of it could not be properly understood—or was even misunderstood—by the authors of the *Jyotisa* texts.

With this point about the antiquity of its astronomical content, we now pass on to consider an information contained in the *Vedanga Jyotisa* which, though astronomical in nature, helps us to locate the region in which this astronomy presumably developed. We are going to see that this again seems to be a pointer to the frontier of the Indus civilization.

Let us first try to be clear about the data itself.

According to *Vedanga Jyotisa,* one solar year consists of 366 civil days (a civil day meaning the time from one sunrise to the next, i.e. a day-sum-night or nycthemeron, consisting

77. G. Thibaut, in SHSI II, 480 ff.
78. *Panca Siddhantika* Verse-4. See also S. B. Dikshit, BJS pt. II, p. 3.
79. G. Thibaut, in SHSI II, 488.
80. VJ—J, verse 28.

of our 24 hours).[80] One solar year consists of two equal *ayana*-s,[81] i.e. in each *ayana* there are 183 nycthemeron. The two *ayana*-s are : 1) *uttarayana,* i.e. the period beginning with the winter solstice and ending on the day just preceding the summer solstice, and 2) *daksinayana,* i.e. the period beginning with the day of the summer solstice and ending with the day just preceding the winter solstice. The text further asserts that during the *uttarayana* each day (from sunrise to sunset) increases by one *prastha* (the meaning of which we shall presently see) and the night decreases by one *prastha* ; while during the *daksinayana* the opposite takes place.[82] Further the maximum time difference between a day (i.e. from sunrise to sunset) and night (i.e. from sunset to sunrise) is 6 *muhurta*-s.

What then, are meant by *prastha*-s and *muhurta*-s ?

The contraption presupposed for time-measurement was called *jalayantra*[83] or a vessel with a hole for discharging water from it, and the water discharged from it was measured by units called *prastha.* Accordingly, the word *prastha* was also used as a unit for time-measurement, i.e. the time taken for the discharge of one *prastha* of water from the vessel. According to *Vedanga Jyotisa,* 15¼ (15.25) *prastha* of water is discharged during the time period called one *danda.* Hence was the practice of referring to one *danda* as equal to 15¼ or 15.25 *prastha*-s. Thus, one *prastha* approximately$=0.06557$ (or $^4/_{61}$) *danda*-s. Hence, in one *ayana,* the total increase of a day or a night$=183$ *prastha*-s$=183\times{}^4/_{61}$ *danda*-s $= 183\times 0.06557$ *danda*-s, i.e. 12 *danda*-s. Now, 2 *danda*-s (also called 2 *nadika*-s$=1$ *muhurta*),[84] i.e. 12 *danda*-s$=6$ *muhuta*-s. The *Vedanga Jyotisa* calculates one *savana* day (i.e. one sunrise to the next or our 24 hours) as consisting of 30 *muhurta*-s (i.e. 1 *muhurta*$=$our 48 minutes).

Now, as already stated, for *Vedanga Jyotisa,* the maximum time difference between one day (sunrise to sunset) and one night (sunset to sunrise) is 6 *muhurta*-s. On the starting day

80. VJ-Y, verse 28.
81. *Ibid.*
82. VJ-Y, verse 8.
83. Fleet in JRAS. 1915. 213-230. S. B. Dikshit BJS. 224ff.; S. R. Das in IHQ. 1928. 256-69.
84. VJ-Y, verse 32.

of the *daksinayana* (i.e. summer solstice), the day is longest and the night shortest. Hence, on the summer solstice, the day is 18 *muhurta*-s (=our 864 minutes or 14 hr.s 24 min.s) and the night 12 *muhurta*-s (=our 576 minutes or 9 hours 36 minutes). Similarly, on the winter solstice, the day=12 *muhurta*-s and the night 18 *muhurta*-s.

Such then, is the data we have in the *Vedanga Jyotisa*. And it is exceedingly important for our discussion. According to the astronomical knowledge we now possess, such relation between the longest and shortest day of the year cannot and does not hold good all over the globe. On the contrary, it holds good only for some specified latitude. The point is already noted by earlier scholars. Siteshcandra Bhattacaryya, for example, on whose edition of the *Jyotisa* we have depended here, observes that this phenomenon holds good only for latitude 34°45′ north, though unfortunately he does not give us the calculation on which he depends.[85] Besides, the calculation has to be based on the exact meaning assumed by the text of the concept of sun-rise and sun-set and also certain other points. So I have passed on the data to Ramatosh Sarkar and A. K. Chakrabarty for more precise calculation of the possible latitude from which the observation under consideration could be actual. Taking into consideration various alternative possibilities, Sarkar arrives at the conclusion that the most plausible alternatives are : (1) latitude 34.3° (34°18′) North, or (2) 34.5° (34°30′) North. His calculations and observations are to be found in Appendices. Remarkably enough, these come rather close to the view expressed by Siteshcandra Bhattacaryya and Sarkar explains in the Appendices why his calculations differ marginally from that of Chakrabarty because of some differences in their presuppositions.

With these points in mind, we may return to our main discussion. The astronomical data concerning the longest and shortest day is a pointer to some geographical location. Significantly enough, this geographical location falls within the cultural frontier of the Indus civilization, the latitude indicated being somewhat more to the north of Harappa whose latitude is 30°38′ North, though much nearer to Taxila.

85. S. C. Bhattacharya, *VJ* 18.

It is also significant to note from the point of view of our discussion that the place of observation of the longest and shortest day of the *Vedanga Jyotisa* cannot be true of the regions where the Vedic peoples eventually settled and produced their ritual literature—the *Yajurveda* and the *Brahmanas.* The latitude of the Vedic settlements could not be more than 28° N.[86] Therefore, we are inclined to conclude that in the *Vedanga Jyotisa* we have an important clue which, geographically speaking, indicates that its astronomical contents were presumably based on the observations of the Harappans, though it came down to the much later period and to a different region altogether, where the Vedic priests wanted somehow to connect it with their sacrificial ritual, branding it as a "limb of the Vedas" (*Vedanga*), perhaps without understanding and certainly not verifying the astronomical contents that came down to them. This, for us may be a clue also to the unintelligibility of the text in its codified form.

The observation of the longest and shortest day under discussion gives us only an idea of the latitude and, as such, it holds good of the entire belt of the globe of this latitude, inclusive of Mesopotamia, the southern capital of which, namely Babylonia, has the latitude 32°33′ N. This might have been one of the reasons why it was suggested that the astronomical calculation under consideration developed in Babylonia and the Indians borrowed it from the Mesopotamians. However, apart from the possibility of independent and parallel developments, we have to consider here another point. The *Vedanga Jyotisa* view, as we have seen, is based on certain detailed calculation and also on the use of a certain apparatus for measuring the time-unit. So long, therefore, we do not come across the relevant calculations and the relevant instrument for measuring time-unit in Mesopotamia, the mere fact that the latitude roughly agrees with that of Mesopotamia—combined of course with the fact that the ancient Mesopotamians also developed their system of astronomy—cannot prove that the Indians borrowed the astronomy of *Vedanga Jyotisa* from

86. The Aryavarta of the Dharmasastras is the middle Gangetic zone, extending originally from Kuruksetra to Allahabad.

them. This is a point already argued by Whitney and Thibaut. As the latter put[87] :

> Regarding the disputed point whether the rule fixing the length of the shortest and longest days of the year has been borrowed by the Indians from some foreign source, for instance from Babylon, or sprung up independently on Indian soil, I am entirely of the opinion of Prof. Whitney who sees no sufficient reason for supposing the rule to be an imported one. It is true that the rule agrees with the facts only for the extreme north-west corner of India; but it is approximately true for a much greater part of India, and that an ancient rule—which the rule in question doubtless is—agrees best with the actual circumstances existing in the North West of India is after all just what we should expect.

The last point of Thibaut is in need of some comment. What did he mean by saying that the observation "agrees best with the actual circumstances existing in North West of India" and it is "after all just what we should expect"? Why in particular, it is just what we should expect? The answer appears to us to be as follows. Thibaut's article on the *Vedanga Jyotisa* appeared in 1877, when the only valid starting point for understanding the cultural history of India was the *Rgveda* and when it was practically unanimously assumed that the Vedic people entered India from the North West. Thus, it seems, that Thibaut tacitly assumed that while entering India from the North West the Vedic people actually observed that the longest day consisted of 18 *muhurta*-s and the shortest of 12 *muhurta*-s, which therefore formed part of their assumptions. However, there are many considerations against such a possibility. If the Vedic people actually observed such a phenomenon while they were enterning India from the North West, it is only reasonable for us to expect some reference to it in the earliest strata of the *Rgveda*. But the fact is that the entire *Rgveda* is totally unaware of any observation even remotely suggesting this. Secondly, there is little scope to doubt that when the Vedic people entered India, they were on the whole nomadic pastoral people, for whose economic life astronomical knowledge could not be a necessity, though when they settled down many centuries later in the "Aryavarta" (or "Madhyadesa"), astronomical knowledge could be—and perhaps did—form part of the

87. G. Thibaut, in SHSI, II. 488.

need of their economic life, though it seems that they depended for this purpose more on surviving hearsay than on actual observations. Thirdly, from what we actually read about the technological development of the Vedic people in the *Rgveda* itself, it requires a great deal of Aryan chauvinism to imagine that during this period of the oral composition of this vast literature they could by any chance improvise the time-measuring instrument—something quite sophisticated as judged in the ancient context.

But what could Thibaut do in 1877 when absolutely nothing was known about the Harappan civilization in North West India with its imposing technological development and producing the vast agricultural surplus on which the civilization thrived? The strong presumption is that their socio-economic life did require an astronomical system, though at the present stage of research, in default of any direct documentary evidence of this astronomical system, we are somewhat obliged to follow the method of retrospective probing to understand it. Fortunately, the method seems to yield some positive result, for in the literature of the Vedic peoples—which is much later than the Indus civilization—we have both chronological and geographical pointers to some system of astronomy already developed in the Indus civilization.